# Drive Clean Program Emissions Benefit Analysis and Reporting – Light Duty Vehicles and Non-Diesel Heavy Duty Vehicles – 1999 to 2005

**June 2007**

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## EXECUTIVE SUMMARY

Vehicles are the largest single domestic source of smog-causing pollutants in Ontario. Drive Clean reduces smog-causing emissions as well as other pollutants by requiring vehicles to have their emissions tested before their licence plates can be renewed or before transfer of ownership. The test identifies vehicles with emissions problems and requires them to be repaired.

The Light-Duty Vehicle (LDV) test process comprises three steps:

- A pretest check to ensure the vehicle is suitable and safe to test;
- A tamper-proof tailpipe emissions test done on a dynamometer (known as an ASM test), to determine the concentrations of hydrocarbons (HC), carbon monoxide (CO), and nitrogen oxides (NOx) in the LDV exhaust;
- Immediately following the ASM test, a test at curb idle for emissions of HC and CO.

To pass, the concentration of all polluting gases must be at or below the provincial emissions standards during the ASM and curb idle tests.

LDVs that do not meet the standards require repairs and retests until they receive a Pass or Conditional Pass. A vehicle owner must spend no more than a total of $450 on a diagnostic check of the problem and on emissions-related repairs at a Drive Clean accredited facility to qualify for a Conditional Pass. A Conditional Pass will be issued when a vehicle fails its retest if repairs were performed by a certified Drive Clean Repair Facility.

All Non-Diesel Heavy Duty Vehicles (NDHDVs) and some LDVs, that can not be tested on a dynamometer, are tested at high-idle (2500 rpm) and at curb idle, for just HC and CO. To pass, the concentration of all polluting gases must be at or below the provincial emissions standards. NDHDVs that do not meet the standards require repairs and retests until they receive a Pass; a Conditional Pass is not available for NDHDVs.

### Test and Failure Rate Statistics for 2004 and 2005

There were more tests in 2005 (3,035,789) than in 2004 (2,823,584), but only very slightly more than in 2003 (3,024,583). Annual test numbers vary because of the biennial nature of the test program.

- ♦ The Drive Clean program was implemented in three Phases, starting with Phase 1 covering the Greater Toronto Area and Hamilton in April 1999, expanding with Phase 2 covering urban and commuter areas from Windsor to Peterborough in January 2001, and further expanding with Phase 3 to cover all of southern Ontario from Windsor to Ottawa in July 2002. Overall, since initial implementation in each Phase, there has been a continued decrease in the percentage of individual vehicles that failed the initial test (each vehicle counted only once).

**Failure Rates**
= (# vehicles failed initial insp) / (# vehicles with initial insp)

| | phase 1 | phase 2 | phase 3 |
|---|---|---|---|
| **1999** | 16.4% | | |
| **2000** | 14.0% | | |
| **2001** | 12.4% | 14.2% | |
| **2002** | 10.7% | 12.8% | 13.1% |
| **2003** | 10.9% | 11.8% | 12.7% |
| **2004** | 8.7% | 9.2% | 9.6% |
| **2005** | 8.6% | 8.5% | 8.6% |

There has also been an important convergence of the Phases, such that the failure rates for Phases 2 and 3 are now the same as for Phase 1, whereas they were higher in previous years. This suggests that the maintenance and repair work done in previous years has brought Phases 2 and 3 up to a comparable maturity to Phase 1.

**Emissions Inventory Reductions**

Total emissions from LDVs in normal on-road use, without a vehicle emissions control program like Drive Clean in place can be estimated using the MOBILE 6.2C vehicle emissions computer model, developed by the United States Environmental Protection Agency and modified by Environment Canada and the Ontario Ministry of the Environment for Canadian vehicles. These total emissions are considered the default inventories for each of the pollutants.

Total emissions from LDVs with Drive Clean in place were estimated independently by using tailpipe test data collected directly from the Drive Clean program each year. These annual emissions were estimated in two stages: the first stage totaled the emissions from all LDVs prior to any repairs being done in the year, and the second stage lowered those totals by the emissions reductions from repairs during the year. These direct estimates were made independently from the MOBILE model.

Repairs lower vehicle emissions, and lowering vehicle emissions lowers the overall vehicle emissions inventory. The percentage of inventory reductions due to new repairs in 2004 and 2005 show the same convergence of Phases as is evident from the failure rates.

| | **HC** | **CO** | **NOx** |
|---|---|---|---|
| **Phase 1** | 7.9% | 8.1% | 4.8% |
| **Phase 2** | 7.5% | 7.6% | 4.2% |
| **Phase 3** | 4.0% | 4.9% | 2.8% |

**Overall Percentage Emission Reductions from 2004 Repairs**

| | **HC** | **CO** | **NOx** |
|---|---|---|---|
| **Phase 1** | 7.2% | 7.9% | 5.6% |
| **Phase 2** | 6.2% | 6.6% | 4.5% |
| **Phase 3** | 5.3% | 6.6% | 4.4% |

**Overall Percentage Emission Reductions from 2005 Repairs**

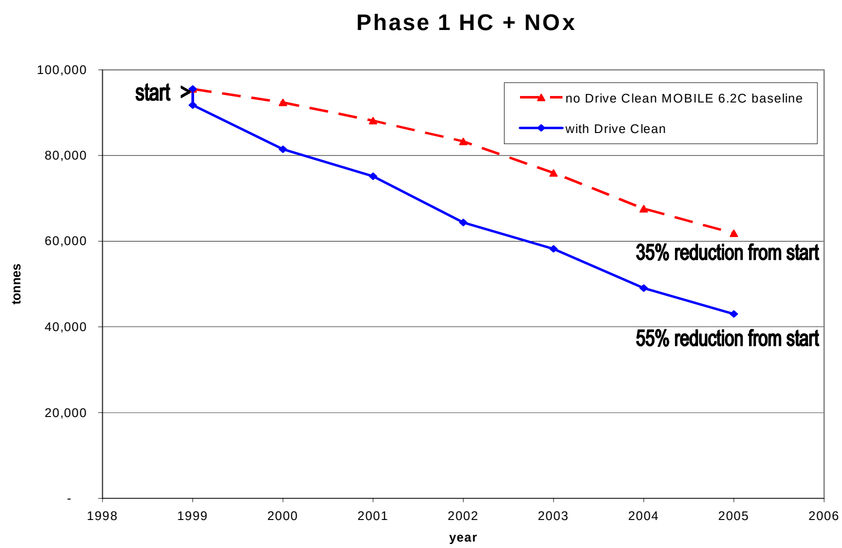
As vehicles in all three Phases have had several test cycles in which failing vehicles have been repaired, the emissions inventory each year depends on those "old" repairs in previous years (stage one of the estimate) and "new" repairs (stage 2 of the estimate) in the year in question. The legacy from the "old" repairs is becoming an increasing portion of the annual reductions as the vehicle fleet gets "cleaner".

The MOBILE and direct emissions estimates use different approaches and provide different results. The MOBILE model is a general evaluation of emissions from all LDVs under all expected driving conditions, whereas the independent estimate evaluated specific Drive Clean tailpipe results. Both estimation approaches make many assumptions and apply factors based on previous information. So it is reasonable to take a cautionary approach and apply an uncertainty factor to the emissions results especially when the results from two approaches are compared. We suggest that ± 20% is a reasonable uncertainty factor that could be applied to both the MOBILE and SBA estimates to avoid overestimating program benefits in such a comparison. As the MOBILE inventories are considered the default and are applied throughout North America, then the cautionary principle suggests that the full 40% (20% + 20%) uncertainty should be applied to adjust the direct emissions estimates with Drive Clean in place. This lowers the SBA emissions reductions

estimates. We are confident that the adjusted results are a conservative minimum estimate of Drive Clean Program benefits.

### Change in Emissions Since the Start of Drive Clean

Since implementation of each Phase, the emissions inventories with Drive Clean in place have decreased substantially faster than the default inventories (emissions that would have been expected without Drive Clean) calculated by MOBILE 6.2C. This is the intended effect of the program. The following chart shows how much the smog-causing emissions (HC + NOx) have decreased in Phase 1 since implementation in 1999 (with the adjustment), compared to how much decrease would have happened without the program. Compared to the starting year, 1999, both decreases are substantial (without Drive Clean, emissions would have decreased by an estimated 35%; with Drive Clean emissions by an estimated 55% by 2005). Other Phases have similar patterns of emissions reductions. The difference between the two emissions inventory lines on the chart calculated for each year provides a conservative annual estimate of how much further emissions have been reduced with Drive Clean in place.




**Annual Emissions Reductions**

### Total Emission Reductions since Start of Drive Clean

The total emissions reductions due to Drive Clean, since first implementation in 1999, have been derived by adding the annual differences between the emissions inventories for each year since then. They total 83,365 tonnes of HC; 1,465,127 tonnes of CO; 67,610 tonnes of NOx, and150,976 tonnes of HC+NOx.

### Fuel Consumption and $CO_2$ Emissions

During 2004 and 2005, 452,558 vehicles failed their initial emissions test and were repaired partially, or completely. These repairs are estimated to save about 29 million litres of fuel over two years. This represents a reduction in carbon dioxide emissions of more than 70,000 tonnes.

Carbon Dioxide emission reductions from the start of the program in 1999 to 2003 were previously estimated at 100,000 tonnes. So the total savings from 1999 to 2005 were about 170,000 tonnes.

**Repairs**
The detailed repair data for 2004 and 2005 follows the same pattern as in previous years, with relatively few different diagnostic and repair categories accounting for almost two thirds of all reported repairs. The overall repair success rate was 70% in both 2004 and 2005, meaning that 70% of the vehicles retested actually achieved a Pass. An additional 22% of repaired vehicles achieved a Conditional Pass, meaning that they were partially repaired for a cost no more than the $450 limit, but their emissions were not reduced enough to pass the retest.

**Heavy-Duty Non-Diesel Vehicles**
The amount of test data for heavy-duty non-diesel vehicles continues to vary each year, but the percentage emission reduction achieved has stayed about the same. However, there are so few of these NDHDVs that their contribution to the emission inventory, and the inventory reductions achieved, are small compared to the LDV fleet.

# 1 INTRODUCTION

Ontario's Drive Clean is a mandatory test and maintenance program for both light and heavy duty vehicles that are required to meet emissions standards as a condition of vehicle registration or transfer of ownership (resale).

This report presents a summary of the analysis of Light-Duty Vehicle (LDV) and Non-Diesel Heavy Duty Vehicle (NDHDV) data collected from the tailpipe emissions test and repair procedures, during the period of January 2, 1999 to December 31, 2005.

Results include estimates of reductions of smog-causing emissions of nitrogen oxides (NOx), and hydrocarbons (HC), and emissions of the poisonous gas carbon monoxide (CO) from LDVs in:

- Phase 1 (Greater Toronto Area and Hamilton, where mandatory emissions testing for Drive Clean began in April 1999);
- Phase 2 (urban and commuter areas from Windsor to Peterborough, where mandatory emissions testing began January 1, 2001);
- Phase 3 (the remainder of southern Ontario from Windsor to Ottawa, where mandatory vehicle emissions testing began on July 1, 2002).

Results also include estimates of reductions of HC and CO from NDHDVs in the same areas as the LDV program.

In the previous report covering the period 1999-2003, reductions of smog-causing emissions were reported as percentages and tonnages achieved during that period in all three Phases. As with the previous report, this report uses the current MOBILE 6.2C vehicle emissions model to estimate start-up baseline emissions as well as "ongoing" baseline emissions that would have been expected without a vehicle test and maintenance program. The MOBILE 6.2C model is described in the previous report. The baseline and ongoing emissions estimates include the effect of factors such as vehicle retirement, improvements in vehicle technologies and cleaner fuels that would have happened even if the Drive Clean program had not been implemented.

Reductions in vehicle emissions result from repairing vehicles that fail the Drive Clean test in combination with vehicle retirement, improved emissions control technologies on new vehicles and improved fuels. Emissions reduction estimates in this report focus on the benefits of emissions-related repairs, separate from emissions reductions resulting from the other factors. Repair benefit results include the performance of repairs in the year of the test as well as the carry-over benefit from vehicles repaired in previous years that continue to have reduced emissions. Aside from the repair benefits that can be directly estimated, there are indirect emissions reduction benefits as the program encourages improved vehicle maintenance by vehicle owners and automotive services facilities. This report goes on to examine detailed failure rate statistics and contributions by failure mode, and explains the observed trends with reference to the changing fleet and the continuing effects of the program. The LDV emissions inventory of HC, CO and NOx, is analyzed to find out how it was affected by new repairs, and is compared to the default inventory modeled by MOBILE 6.2C.

This report also estimates emissions reductions of carbon dioxide ($CO_2$), a climate change gas. This estimate assumes that vehicles that failed the emissions test were subsequently repaired, resulting in a modest reduction in fuel consumption. This approach underestimates the effect on fuel consumption reduction from retiring vehicles; and to a lesser extent, replacing vehicles with a newer model; in both cases fuel consumption would usually be reduced more than that possible from repairing the original vehicle. Fuel savings were then converted directly to $CO_2$ reductions, using the same approach described in the 1999-2003 report.

## 2 BACKGROUND

Smog is a serious health issue in southern Ontario. Scientists have found that there is no “safe” level for exposure to smog. Smog-related air pollution is linked to such health effects as premature death, respiratory and heart problems and bronchitis. The Ontario Medical Association’s report issued in June 2005 estimated that air pollution would result in almost 5,800 premature deaths and 17,000 hospital admissions that year. The OMA also estimated health care costs in 2005 at $507 million and total economic costs of air pollution at $7.8 billion.

Emissions from on-road vehicles contribute to environmental problems with local to global impacts - smog and climate change. Vehicles are the largest single domestic source of smog-causing pollutants in Ontario. Smog-causing emissions from vehicles include the gases NOx and HC. Hydrocarbons are mostly unburned gasoline and belong to a group of pollutants called volatile organic compounds (VOCs). NOx plus VOCs combine in the presence of sunlight to form ground-level ozone, a major component of smog. Vehicle emissions also contain the poisonous gas CO, air toxics such as Benzene, the climate change gas $CO_2$, and microscopic particulates.

Drive Clean reduces smog-causing emissions as well as other pollutants by requiring designated vehicles to have their emissions tested before their licence plates can be renewed or before transfer of ownership. The test identifies vehicles with emissions problems and requires them to be repaired.

### 2.1 New Vehicle Emissions Standards

Federal regulations set emissions performance standards that all new model vehicles must meet in grams of emissions per kilometre. In the United States, emissions standards are expressed as grams per mile. These emissions standards are now uniform throughout Canada and the United States, except for some US states such as California where standards are more stringent. A number of other states have followed suit. New vehicle emissions standards have been progressively tightened in concert with the improvements in emissions control systems introduced over the last 20 years. Manufacturers demonstrate compliance by submitting samples of their new vehicles, representing every new make and model, to the comprehensive Federal Test Procedure (FTP). The FTP is a lengthy series of emissions tests performed on new vehicles, under a variety of controlled ambient conditions and driving cycles which include acceleration, deceleration and idle.

### 2.2 Ontario’s In-Use Vehicle Emissions Standards

Ontario sets standards limiting the permissible release of emissions from in-use on-road vehicles. Emissions from individual vehicles increase over time with engine wear, improper or irregular maintenance, and tampering with, or failure of, the emissions control devices. Some deterioration happens even with well-maintained vehicles. Ontario's vehicle emissions standards, originally based on the FTP standards, have been converted to concentrations (parts per million or percentage), and adjusted to reflect the relative capabilities of both older and newer emissions control systems and the effects of normal engine wear during the lifetime of the vehicles in the Drive Clean program.

Older vehicles, even when maintained in excellent running condition, cannot match the pollution control efficiencies of today's models, but they will be able meet the Drive Clean emissions standards as long as their engines and pollution control systems are operating properly. Conversely, when emissions control systems fail, even today’s model vehicles may become gross polluters.

### 2.3 Mandatory Emissions Testing Requirements

Mandatory emissions testing requirements are found in Ontario Regulation 628 under the Highway Traffic Act. The regulation states that LDVs with a registered gross weight of 4,500 kilograms or

less (passenger cars, sports utility vehicles, vans and light trucks) and NDHDVs with a registered gross weight greater than 4,500 kilograms must obtain an emissions test report for:

- registration renewal, starting for LDVs***** three calendar years after the model year and every second year up to and including 19 calendar years after the model year. A Pass or Conditional Pass (using repair cost limit) report may be used to satisfy this requirement.
- registration renewal, starting for NDHDVs***** three calendar years after the model year and every year with no age limit. A Pass report is required to satisfy this requirement;
- resale: new owner requires a Pass report to purchase a licence plate sticker for the vehicle starting one calendar year after the model year (both LDVs***** and NDHDVs), and up to and including 19 calendar years after the model year (LDVs only; no age limit for NDHDVs). A Pass report is required to satisfy this requirement.

**** Note: In 2006 Drive Clean made changes to the model years included in the program. This report covers a period that ended before those changes were implemented.***

In the biennial LDV test cycle, odd model-year vehicles are tested in an even calendar year; even model-year vehicles are tested in an odd calendar year. Thus, in 2004, emissions tests were mandatory for registration renewal of odd model year vehicles from 1985 to 2001, and in 2005, emissions tests were mandatory for registration renewal of even model year vehicles from 1986 to 2002.

Note that the emissions Pass and Conditional Pass reports are valid for one year so that the test may be done at any time within the12 months prior to the registration expiry date, or the application date for late renewals or ownership transfer. This means that some vehicles will be tested “off cycle” (e.g., many even model year vehicles due for registration renewal early in 2005 were tested in late 2004). The combined effect of on-cycle and off-cycle renewals and tests for ownership transfers means that more than half of the LDVs requiring tests in the biennial cycle were actually tested in any 12-month period.

### 2.4 Emissions Testing

Drive Clean emissions testing is designed to identify vehicles that no longer operate in compliance with acceptable emissions standards, and to ensure that emissions reductions are actually achieved when these vehicles are repaired. The Drive Clean emissions test procedures are set out in Ontario Regulation 361/98, as amended, under the Environmental Protection Act. Emissions standards, emissions test methods and additional technical information are described in greater detail in the Ontario Ministry of Environment’s Drive Clean Guide and the manual of Standard Operating Procedures for Ontario's Drive Clean Facilities as Applied to LDVs and Non Diesel Heavy Duty Vehicles. Since the initial program launch in 1999, several program changes have been made to improve program effectiveness:

- January 1, 2001, program expanded to Phase 2;

- July 1, 2001 the repair cost limit of $200 in place since the start of the program in Phase 1 increased to $450;

- July 1, 2002 the program was expanded to Phase 3 with a repair cost limit of $200 for the next two years, and the curb-idle test was added to the existing dynamometer test in all Phases;

- January 1, 2003:
    - Drive Clean tightened emissions standards for LDV by 11.5%
    - the repair cost limit of $200 in place since the start of the program in Phase 2 (January 1, 2001) increased to $450.

- July 1, 2004, the repair cost limit of $200 in place since the start of the program in Phase 3 was increased to $450.

- January 1, 2005, Drive Clean tightened emissions standards for LDV by a further 11.5%, resulting in standards 23% tighter than the original pre-2003 values.

- May 1, 2005, Drive Clean exempted hybrid vehicles from emissions test requirements.

### 2.5 Test Process: LDV

The LDV test process (for non-diesels) consists of the following basic steps (note program changes and dates above):

- a pretest check:
  - ensures the suitability and safety of testing the vehicle on a dynamometer;
  - verification that a catalytic converter (if one was originally installed on that vehicle) and gas cap are in place;
  - non-compliant vehicles are rejected from testing at this stage and not counted as a test.

- an “advisory” check of the on board diagnostic light for 1998 and newer vehicles (vehicle owners are advised if the “check engine” light was on, but their vehicles are not rejected from testing).

- a sophisticated, tamper-proof emissions test done on a chassis dynamometer (vehicle treadmill) that simulates the load applied to a vehicle as it climbs a grade of about three per cent, at a steady 40 kilometres per hour, to determine emissions levels of HC, CO, and NOx in the exhaust (tailpipe) stream.

- immediately following the dynamometer test, a test for emissions at “curb idle” for HC and CO.

For LDVs to pass, the concentration of all three of the polluting gases emitted from the vehicle tailpipe during the dynometer and the curb idle tests must be at or below the provincial emissions standards (also called cutpoints). Vehicles that do not meet the emissions levels, established for a particular model, make and year, require repairs and retests until they receive a Pass or Conditional Pass.

### 2.6 Alternative Test Process: All NDHDVs and Some LDVs

All NDHDVs and a small but increasing percentage of LDVs (e.g., vehicles equipped with full-time, all-wheel drive, certain vehicles with traction control or anti-locking braking systems, or vehicles with lowered suspension or body kits that might be damaged during the test) cannot be tested on a dynamometer. Tailpipe emissions of HC and CO from these vehicles are measured at two operating conditions: a steady 2,500 RPM and at curb idle. NOx is not measured as it is generated only when the engine is under load, not when the vehicle is idling. While the dynamometer test better reflects on-road vehicle emissions performance, emission-related repairs for HC and CO may also result in reductions of emissions of all three gases, HC, CO and NOx.

### 2.7 Retests

Vehicles may be tested more than once in any given period (e.g., the same day, or since the start of the program) for several reasons:

- a vehicle failing to meet emissions standards requires retesting (may be retested as soon as within the same day, and a vehicle may have several retests);
- a vehicle passing a test for licence plate sticker (registration) renewal would require another test for ownership transfer any time after the 12 month validity of the Pass report;
- a vehicle obtaining a Conditional Pass for sticker renewal would require another test for ownership transfer, even the same day, as a full Pass is required;

- a vehicle that is going to be temporarily out of the testing program area when the test is due may be tested up to one year early;
- a vehicle coming up for licence plate sticker renewal in subsequent two-year cycles requires retesting which means that eventually almost every vehicle will have been tested more than once since the start of the program in each phase;
- quality control and quality assurance checks (audits), and other miscellaneous tests.

### 2.8 Repair Cost Limit (RCL) – Conditional Pass

Vehicle tests and repairs are conducted by Drive Clean certified emissions inspectors and repair technicians at Drive Clean Facilities that are accredited by the Ministry of the Environment. Vehicle owners who wish to qualify for the RCL must have all diagnostic and repair work carried out under the supervision of a Drive Clean certified repair technician. If these vehicles then fail the retest, the owners receive a Conditional Pass. The Conditional Pass can be used to renew the vehicle's registration, but cannot be used to transfer ownership (resale).

### 2.9 Test Data

The emissions and vehicle data collected at Drive Clean facilities are automatically uploaded to a central computer database, known as the Drive Clean Vehicle Emissions Transaction System (VETS). The VETS information is analyzed internally for purposes of quality assurance and quality control, to detect any evidence of fraud and to assess the effectiveness of the program. Test results are accessed by the Ontario Ministry of Transportation through the Vehicle Licensing and Control System and used at vehicle licensing offices to process vehicle registrations.

# 3 LDV NON-DIESEL VEHICLES

## 3.1 Failure Rates and Retest Rates

The total numbers of tests, vehicles, failures, and successful repairs etc in 2004 and in 2005 are summarized in **Appendix Table A-1**. Detailed failure rates by vehicle type and model year for 2004 and 2005 are shown in **Appendix Tables A-2a, and A-2b**. All the numbers in these tables refer to numbers of vehicles: each vehicle has been counted only once, identified by its unique Vehicle Identification Number (VIN). So these tables show how many vehicles of each type and model year were tested, how many failed or passed, and how many were retested, passed or received a Conditional Pass. The 2005 data is summarized in the following tables and figures.

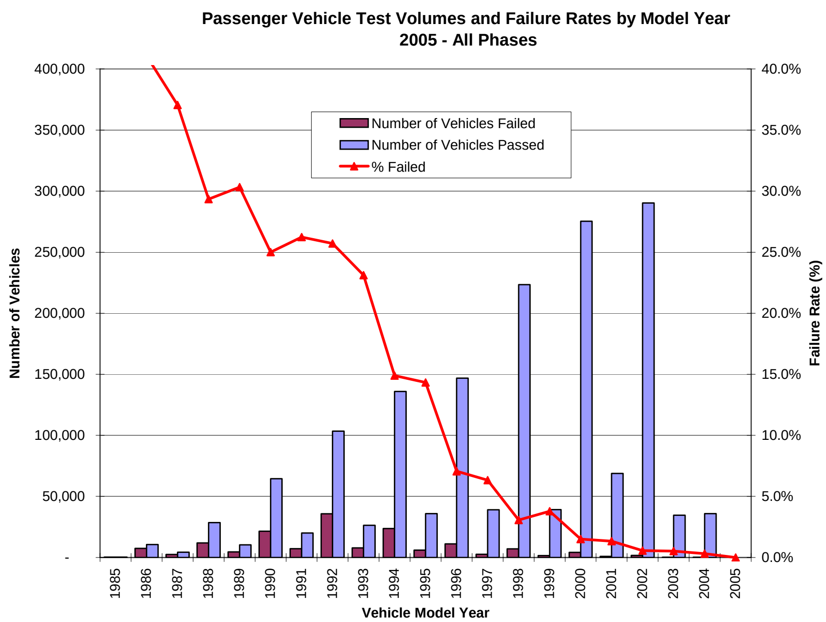



**Figure 1**

**Figures 1 and 2** clearly reflect the biennial nature of the test program, with ‘OFF’ model years trending at a steady fraction of ‘ON’ model years, both for numbers tested, and for numbers failed. The numbers of trucks are consistently lower than the number of passenger vehicles (cars), but are a slightly higher fraction for more recent model years. An increase in the fraction of trucks is important because trucks are certified to less stringent standards than passenger vehicles. So a shift towards trucks instead of cars tends to increase the total fleet emissions inventory, even without any increase in the total number of vehicles, or in the amount they are driven each year.

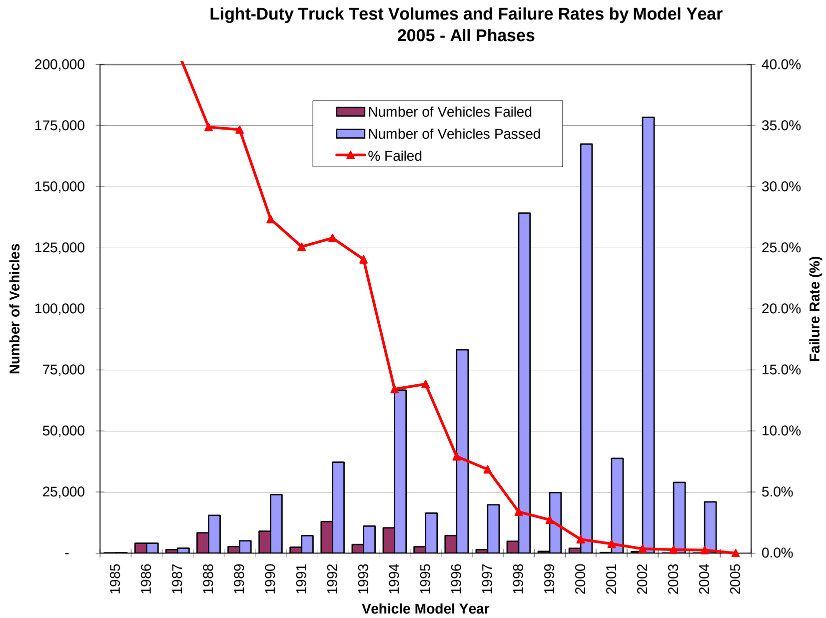



**Figure 2**

The greatest number of vehicles that failed in 2005 were from model year 1992. Prior to model year 1992, the percentage of failing vehicles increased, but fewer vehicles were tested. After model year 1992, more vehicles were tested but the percentage of vehicles failing decreased.

The number of failing vehicles is very important since all of emissions reductions benefits estimated in **section 3.4** of this report are based on repairing those failed vehicles. An important point from these two figures is that although the number of vehicles tested is highest for the newest model years, the number of vehicles that failed has a definite peak at model year 1992. Accordingly, it is clear that the bulk of those benefits in 2005 came from repairing vehicles in the 11 to 15 year age range.

**Figure 1 and 2** also illustrate the very wide range of failure rates, from almost 50% for vehicles about 20 years old to about 25% for those about 13 years old, and down to less than 1% for vehicles less than 5 years old. For each model year, the failure rates were about the same for cars and trucks.

Overall the failure rates for unique LDV VINs in each Phase at the initial test have continued to decrease from previous calendar years, and it is worth noting that the rates are now essentially the same in all Phases (**Table 1**).

## Table 1 Overall Failure Rate Trends

**Failure Rates**
= (# vehicles failed initial insp) / (# vehicles with initial insp)

| | phase 1 | phase 2 | phase 3 |
|---|---|---|---|
| **1999** | 16.4% | | |
| **2000** | 14.0% | | |
| **2001** | 12.4% | 14.2% | |
| **2002** | 10.7% | 12.8% | 13.1% |
| **2003** | 10.9% | 11.8% | 12.7% |
| **2004** | 8.7% | 9.2% | 9.6% |
| **2005** | 8.6% | 8.5% | 8.6% |

## Table 2 Failure Rates and Retest Rates 2004

| 2004 | Number of vehicles | | | | | | % of tested | % of failed | % of retested | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Phase | tested | failed | retested | passed retest | cond pass retest | failed retest | failure rate | retest rate | retest pass rate | retest con pass rate | retest fail rate |
| 1 | 1,286,556 | 111,585 | 68,108 | 51,032 | 11,247 | 17,564 | **8.7%** | 61.0% | 74.9% | 16.5% | 25.8% |
| 2 | 779,791 | 72,040 | 48,002 | 33,927 | 10,198 | 12,157 | **9.2%** | 66.6% | 70.7% | 21.2% | 25.3% |
| 3 | 461,094 | 44,243 | 28,823 | 15,905 | 11,200 | 5,747 | **9.6%** | 65.1% | 55.2% | 38.9% | 19.9% |
| all | 2,527,441 | 227,868 | 144,933 | 100,864 | 32,645 | 35,468 | **9.0%** | 63.6% | 69.6% | 22.5% | 24.5% |

## Table 3 Failure Rates and Retest Rates 2005

| 2005 | Number of vehicles | | | | | | % of tested | % of failed | % of retested | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Phase | tested | failed | retested | passed retest | cond pass retest | failed retest | failure rate | retest rate | retest pass rate | retest con pass rate | retest fail rate |
| 1 | 1,386,963 | 118,786 | 74,073 | 53,440 | 13,542 | 20,748 | **8.6%** | 62.4% | 72.1% | 18.3% | 28.0% |
| 2 | 835,963 | 71,449 | 47,747 | 32,948 | 10,841 | 12,761 | **8.5%** | 66.8% | 69.0% | 22.7% | 26.7% |
| 3 | 501,008 | 43,032 | 26,566 | 16,392 | 7,766 | 7,000 | **8.6%** | 61.7% | 61.7% | 29.2% | 26.3% |
| all | 2,723,934 | 233,267 | 148,386 | 102,780 | 32,149 | 40,509 | **8.6%** | 63.6% | 69.3% | 21.7% | 27.3% |

The overall percentage of failed vehicles that were presented for retest (**Tables 2 and 3**) in 2005 was 64%, which is the same as in 2004. The success rate for retests continued about the same as previous years, with 70% of retested vehicles achieving a Pass. [1] In 2005, 22% of retested vehicles received a Conditional Pass, and 27% failed. [2]

[1] The numbers in these tables are the numbers of unique vehicles (ie each VIN is only included once in each count) that were tested, retested, failed, etc in the calendar year. Some vehicles were tested or retested more than once, so the numbers of tests and retests were higher than the numbers of vehicles that received tests or retetsts. Many of the vehicles that failed their retests, or only received a Conditional Pass, also went on to have additional repairs and to eventually Pass. This is why the percentages of retest outcomes total to more than one hundred.

[2] It is important to realise that in characterising the inspection experience of each vehicle in **section 3.4** of this report, the methodology is not so simple as described above. That section also considers whether a vehicle was first inspected towards the end of the previous calendar year. So, for example, a vehicle that passed its first test in February 2005, but which had previously failed in November 2004 would be considered as a vehicle that initially failed, and was then repaired to pass, with the emission reduction benefit being credited to a repair. But in the above tables, which are simply a snapshot of what happened in each calendar year, the same vehicle would be counted as having failed in the 2004 table, and passed in the 2005 table.

### 3.2 Contributions of Failure Modes

The frequencies with which tests included the various failure modes are shown in **Appendix Tables A-3a and A-3b**, and are summarized in the following tables. The overall numbers of tests in these tables are higher than the numbers of vehicles which appear in **Tables 2 and 3** and **Appendix Tables A-2a and A-2b**, because there are some vehicles which undergo more than one test in a calendar year.

**Table 4 Contribution of Failure Modes – 2004**

| 2004 | Number of Tests | | | | | | | failure rate as % | Percentage of Failed Initial Tests | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Phase | init tests | failed init test | include idle HC failure | include idle CO failure | include ASM HC failure | include ASM CO failure | include ASM NO failure | of init tests | include idle HC failure | include idle CO failure | include ASM HC failure | include ASM CO failure | include ASM NO failure |
| 1 | 1,355,414 | 126,245 | 41,831 | 34,225 | 82,677 | 51,852 | 68,895 | 9.3% | 33.1% | 27.1% | 65.5% | 41.1% | 54.6% |
| 2 | 813,759 | 81,230 | 28,672 | 24,141 | 53,597 | 31,914 | 39,805 | 10.0% | 35.3% | 29.7% | 66.0% | 39.3% | 49.0% |
| 3 | 477,632 | 49,099 | 17,574 | 14,682 | 29,998 | 19,246 | 25,368 | 10.3% | 35.8% | 29.9% | 61.1% | 39.2% | 51.7% |
| all | 2,646,805 | 256,574 | 88,077 | 73,048 | 166,272 | 103,012 | 134,068 | 9.7% | 34.3% | 28.5% | 64.8% | 40.1% | 52.3% |

**Table 5 Contribution of Failure Modes - 2005**

| 2005 | Number of Tests | | | | | | | failure rate as % | Percentage of Failed Initial Tests | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Phase | init tests | failed init test | include idle HC failure | include idle CO failure | include ASM HC failure | include ASM CO failure | include ASM NO failure | of init tests | include idle HC failure | include idle CO failure | include ASM HC failure | include ASM CO failure | include ASM NO failure |
| 1 | 1,454,937 | 133,634 | 32,954 | 27,372 | 81,566 | 54,808 | 84,406 | 9.2% | 24.7% | 20.5% | 61.0% | 41.0% | 63.2% |
| 2 | 869,599 | 81,028 | 22,040 | 18,492 | 50,891 | 31,539 | 47,021 | 9.3% | 27.2% | 22.8% | 62.8% | 38.9% | 58.0% |
| 3 | 521,311 | 49,511 | 13,464 | 11,334 | 29,369 | 19,476 | 29,010 | 9.5% | 27.2% | 22.9% | 59.3% | 39.3% | 58.6% |
| all | 2,845,847 | 264,173 | 68,458 | 57,198 | 161,826 | 105,823 | 160,437 | 9.3% | 25.9% | 21.7% | 61.3% | 40.1% | 60.7% |

The most common failure mode overall was for ASM HC. Next most common was ASM NOx. ASM CO failure was in third place. The idle failure modes were less frequent and appeared in less than a quarter of all failures. Most failures included more than one failed component mode.

The frequency of idle failures has decreased as a fraction of all failures, but the frequency of ASM NOx failures in the ASM test has increased. Both effects are partly caused by the rolling window of model years subject to the program: idle failures are more common for the oldest technology vehicles that have been gradually excluded from the program, while NOx failures are more common for newer technology vehicles that are increasingly comprising the overall vehicle fleet.

**Figure 3** shows the modal failure rates as a function of model year, in 2005. Idle failures were generally more common for the oldest vehicles tested, and idle failures for both gases, HC and CO, followed a similar pattern throughout all model years.

ASM failure modes decreased rapidly for the oldest vehicles, but this may be an artifact because, in general, the oldest LDVs requiring a test in 2005 were model years 1986 and newer. It is possible that those older vehicles actually tested were not typical of the majority of vehicles of that age. Of more significance is what happened around model year 1998. In 1998 Tier 1 certification standards were fully mandated for Canada. In the US, they had been phased in from 1994 to 1996,

and Canada adopted the Tier 1 tailpipe standards in 1996; but Canada did not require vehicles to comply with OBDII requirements until the 1998 model year. Tier 1 standards differed from the earlier Tier 0 standards by lowering allowable NOx emissions and introducing a non-methane hydrocarbon (NMHC) standard for all LDVs, and lowering allowable total hydrocarbon (THC) emissions for LDV trucks. The Drive Clean results show that from model year 1998 onwards, HC failure was much less of a factor, dropping from about 60% of all failures to less than 30% by model year 2003. The contribution of NOx failures shows a substantial decrease from model year about 2002 onwards. This may be because of improved NOx control technology introduced to comply with the US NLEV program, and in anticipation of Tier 2 standards. The NLEV program took effect in the North Eastern states in 1999, and nationally in 2001. It required vehicles to meet standards basically equivalent to California LEV standards. Tier 2 standards were introduced in 2004, and have average NOx requirements much lower than Tier 1.

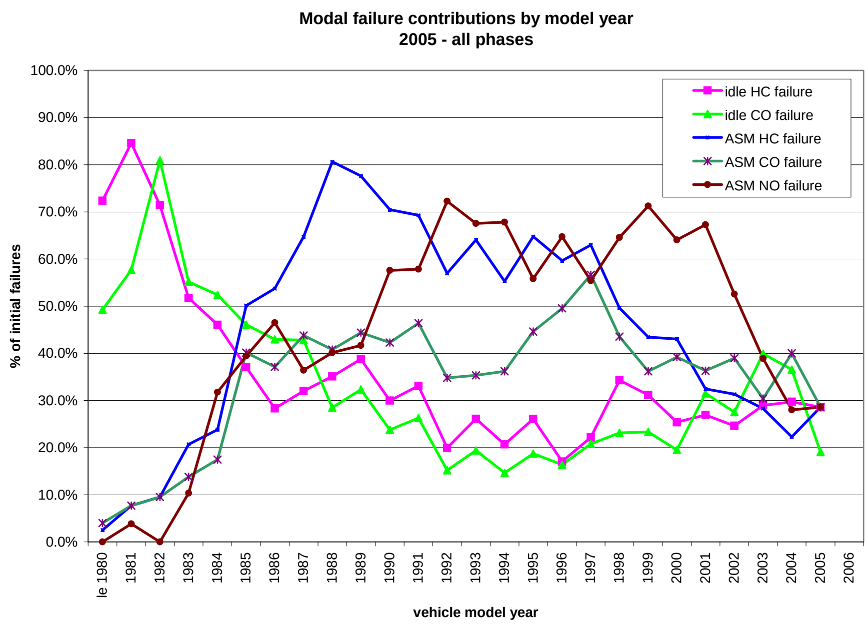



**Figure 3**

### 3.3 Reduction of Average Drive Clean Test Readings

Before proceeding to estimate how much the light-duty vehicle mass emissions inventory has been reduced by the Drive Clean program, it is worthwhile to consider how the average emission test readings have changed over time. The trend is best illustrated by the readings from Phase 1, because they extend over the longest period. In 1999 the average emission test readings were HC = 57 ppm; CO = 0.33%; and NOx = 446 ppm. In 2005 the average readings for all tests in Phase 1 reduced to HC = 24 ppm; CO = 0.12%; and NOx = 177 ppm. The proportions by which the readings came down are plotted in **Figure 4**, and it is clear that average 2005 readings were about 60% lower than average 1999 readings. The change of average readings only applies to the specific operating condition of the test, and therefore is only an indicator (rather than an actual measure) of how overall emissions have reduced over time. But the indication is that the combined effects of vehicle turnover to newer technology, together with the Drive Clean repairs and other factors, has made a significant impact on overall emissions.

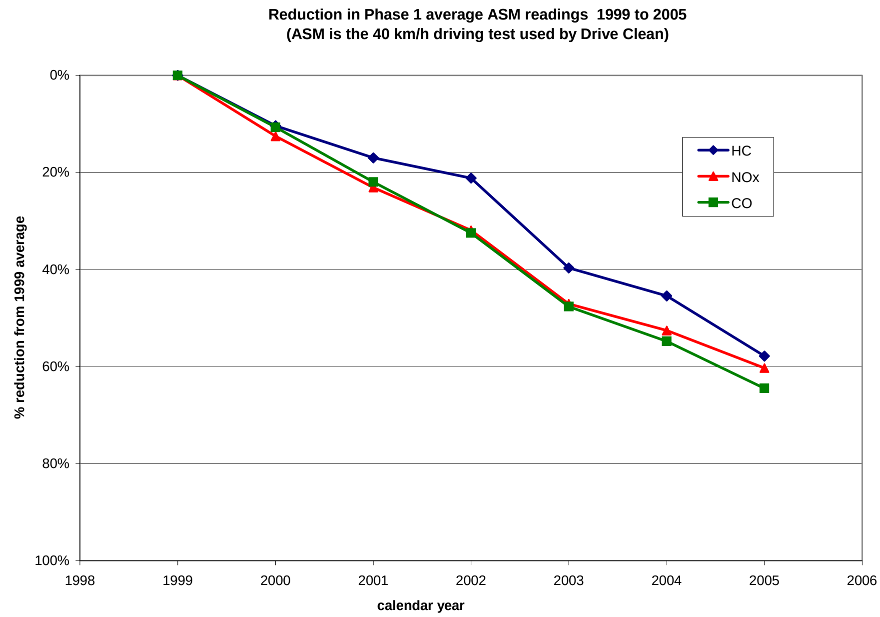



**Figure 4**

## 3.4 Mass Emissions and Inventory Reductions

### 3.4.1 Calculation Methodology

The mass emissions for the entire light duty fleet, and the effect of emission repairs, have been calculated in the same way as for previous calendar years. The method uses input data derived from the test results; the vehicle registration and licensing records; and from tables of mass emission factors.

One way to think of the approach is to consider the test program as a very large annual survey of the state of the fleet, which examines over half of the registered vehicles every year (additional tests result from requirements for ownership transfer). In fact, the data provide two surveys each year. The first comprises the initial test results obtained by all the vehicles when they are first presented for testing. This survey data indicates the overall condition of the fleet if no more repairs were going to be required in the year. The second survey comprises the final test results for all vehicles; so it is different from the first in that the vehicles that initially failed were since repaired and should have returned to pass a retest. Comparing the two surveys indicates how much new benefit is attributable to the repairs performed in the year. Another aspect of the analysis is longitudinal, and compares the survey results from one year to the next. The overall inventory reductions achieved over time are derived from comparing each year's assessment with the assessments of previous years. This part of the analysis indicates how the inventory has reduced overall, from all possible causes, which include things such as fleet turnover; better preventive maintenance; etc as well as the effects of new repairs, and the continued legacy of older repairs.

The first step was to stratify all the vehicles in terms of their age; vehicle type; and test result. The test result is characterized by the combination of pass and fail modes. There are eight possible combinations for the ASM test which comprises pass or fail for each of HC, CO and NOx. If a vehicle passed all components of the ASM, its idle result was considered, and this has four possible combinations of pass or fail for each of HC and CO. Thus there are a total of eleven possible combination modes: 7 ASM failure modes; 3 idle failure modes; and a pass in all modes. The failure mode combinations are as follows:

| | HC | CO | NOx |
|---|---|---|---|
| **ASM failure modes** | P | P | F |
| | P | F | P |
| | P | F | F |
| | F | P | P |
| | F | P | F |
| | F | F | P |
| | F | F | F |

| | HC | CO |
|---|---|---|
| **Idle failure modes** | P | F |
| | F | P |
| | F | F |

All the tested vehicles were counted in each stratification.

Those vehicles that failed and later returned for another test that either received a Pass or Conditional Pass were counted separately - again in terms of vehicle type, age group and initial failure mode. Those that eventually passed were counted separately from those that only achieved a Conditional Pass. Individual vehicles having both Conditional Pass and then Pass results on subsequent tests were counted only as Passes.

In performing these counts, the effect of carry-over from the previous calendar year was included. The only vehicles counted as 'Passed First Time', were those that passed their first attempt at test, without having previously failed in the calendar year, or in last three months of the previous calendar year. Any vehicles which had initially failed in last three months of the previous year, but then came back to Pass or Conditionally Pass in the next year, were counted as 'Repaired to Pass' or 'Repaired to Conditional Pass'.

The second step was to allocate appropriate 'Pass' or 'Fail' characteristics to all the vehicles which were licensed but not tested. The purpose of this was to be able to model their emissions. It was assumed that within each age group and vehicle type combination the overall emissions characteristics of those vehicles not tested would fall into approximately the same pattern as was found for those vehicles which were tested. This is a fairly conservative assumption, because most of the tested vehicles would have gone two years since their last test, but most of the not-tested vehicles would have been tested, and repaired if necessary, only one year earlier. So any deterioration would be less severe in the not-tested vehicles, and their overall emission characteristics should really be somewhat better than those of the vehicles which were tested in the calendar year.

To calculate the initial LDV fleet emissions in the calendar year, without the benefit of any new repairs, the number of vehicles in each stratification was multiplied by their annual kilometres and the appropriate emission factors. The mass emission factors are the emission rates (in gram/km) for each combination failure mode, of each vehicle type and age group. This calculation was done for each stratification and emission, and then they were totaled. The result indicates what the overall emissions rate would be if no new repairs had been performed in the year.

For example, the aggregate calculation for HC was done as follows:

$$\text{Initial HC} = \sum_{\text{passing vehicles}} \text{g/km} \times \text{km/year} + \sum_{\text{failing vehicles}} \text{g/km} \times \text{km/year} + \sum_{\text{exempt vehicles}} \text{g/km} \times \text{km/year}$$

where:

$\Sigma$ = sum for all vehicles in the group
g/km = mass emissions factor, grams per kilometre
km/year = annual distance driven, kilometres per year

The initial values represent what the inventory would be in the year if no more repairs were made (i.e., if the program requirements were suspended at the beginning of the year). The effects of repairs done in previous years, however, and the better maintenance of vehicles would continue to provide inventory reduction benefits for a number of years afterwards.

A second calculation was then performed which used the ‘repaired to pass’ and ‘repaired to Conditional Pass’ emission factors for all the vehicles counted as fitting those descriptions. The result indicates the overall emissions rate of the LDV fleet as achieved with the new repairs.

$$\text{Final HC} = \sum_{\text{passing vehicles}} \text{g/km x km/year} + \sum_{\text{repaired vehicles}} \text{g/km x km/year} + \sum_{\text{exempt vehicles}} \text{g/km x km/year}$$

The final values represent the estimated “actual” inventory that was achieved by the end of each year.

- The difference between the two results indicates the benefit that has been derived from the new repairs in the calendar year.

  thus: Reduction of HC from New Repairs = Initial HC - Final HC

- Comparing the final values from one year to the next shows how the estimated overall inventory has decreased.

The two final parts of this calculation are illustrated by **Figure 5**, which actually plots the calculation results for HC+NOx for Phase 1 from 1999 to 2005. In each calendar year the Initial and Final emissions, derived from the Initial and Final ‘surveys’, are the two vertically aligned points. The amount by which emissions were reduced in the year by new repairs, is indicated by their vertical separation. The sloped line that connects to the next year, indicates the additional reduction that was achieved by all other factors combined, from the final result of one year to the initial result of the next. Normally only the final emissions results from each year’s survey are plotted (i.e., lower points each year are connected).

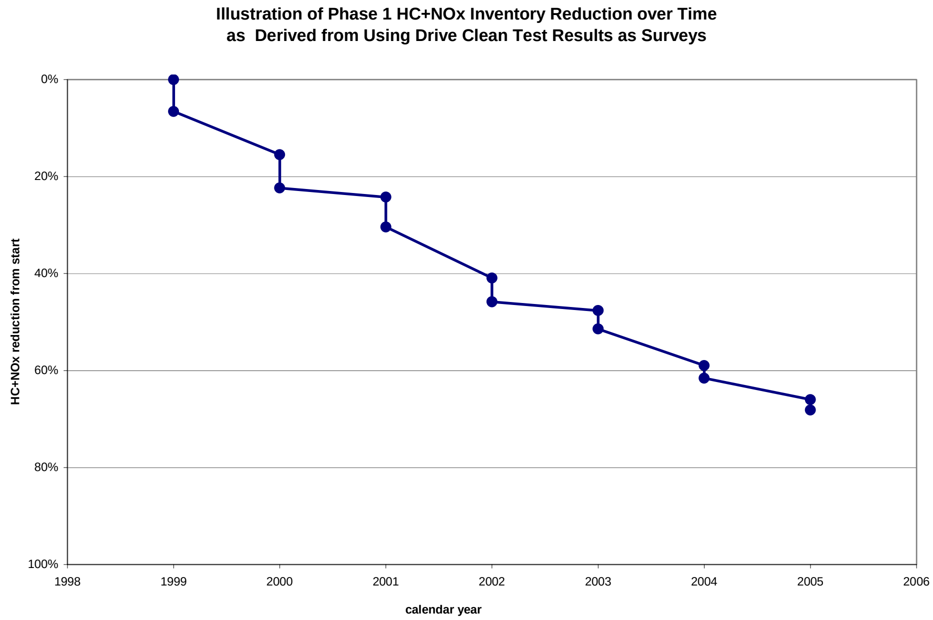



**Figure 5**

### 3.4.2 Annual Kilometres Driven per Vehicle

The odometer readings from the 2004 and 2005 test database were combined with those from the same vehicles tested in 2002 and 2003 in order to derive average annual kilometres-driven by age group. The method used was the same as has been described previously, but this was the first time that the calculation could also be done for Phase 3 as well as the other Phases, because 2003 was the first full year for Phase 3. It was established that the profile by vehicle type and model year was the same for all Phases. **Figure 6** shows the average for all Phases, of kilometres traveled per year, by vehicle type and model year. For the newer vehicles, trucks were driven a little more on average than passenger vehicles. But for vehicles at about the 1992 model year and older, cars and trucks were driven about the same amount. The amount that vehicles are driven appeared to stay about the same until they reach about 8 or 9 years old, and then they are driven less each year as they age.

For the emission reduction calculation, the average km/year was calculated for cars and for trucks, for each of the age groups used in the calculation. For the oldest vehicles, over 20 years old, the data is unreliable because of very small sample sizes, so values were extrapolated backwards from later model years.

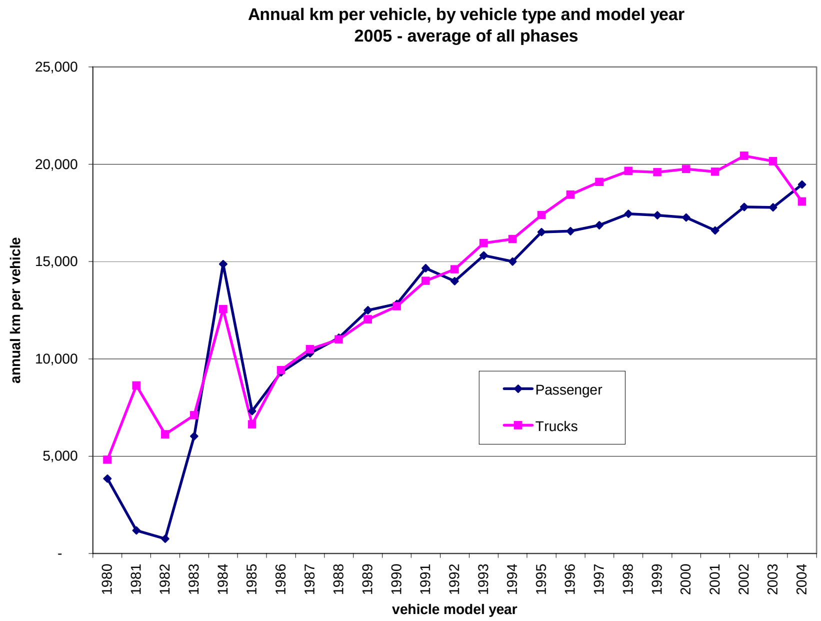



**Figure 6**

### 3.4.3 Mass Emission Factors

Two of the three major inputs to the emission reduction model are naturally updated each year. These are the test data itself, and the overall fleet registration and licensing data. The third major input comprises a set of mass emission factors, which do not require such regular updating, because they remain valid for some time.

For previous published analyses, the mass emission factors were derived from a sample testing program in British Columbia which ended in 2000. That program conducted Hot505 mass emission tests on vehicles which also had ASM and idle results, and it allowed the allocation of mass emission rates to various stratifications of vehicle type, age group, and ASM+idle test results. These tests were replaced by a program of full-duration IM240 testing which also collects second-by-second exhaust concentration readings, but this IM240 data does not include information about what ASM and idle test results would have been achieved.

Therefore, in order to create an updated table of mass emission factors, a project was undertaken during 2005 which required the synthesis of ASM and idle readings from the second-by-second concentration values from IM240 testing. These synthetic readings were used to determine what pass and failure modes would have been experienced by each vehicle if it had been subjected to ASM and idle testing. Averaging the mass emissions for each stratification of vehicle type, age group, and pass/failure mode provided a dataset of mass emission factors in the same form as the previous one.

The update was required to provide more valid modeling of the emission performance of the newer vehicles. Understandably, no 2001 and newer vehicles appeared in the test data which had been collected up to calendar year 2000. Also, the amount of data for vehicles of model years 1997 to 2000 was limited because few had been inspected up to that time.

This meant that the existing table of mass-emission factors was based on reliable test data for vehicles up to about model year 1996. Until recently, the table was adequate for the purpose of calculating the amount of emission reductions achieved by repairs to vehicles that failed the Drive Clean test since most failing vehicles were model years 1996 and older.

Effect of Factors on Newer Failing Vehicles

As the mass emission factors for model years 1997 to 2000 were based on much sparser test data, interpolation, based on the known developments in initial vehicle emissions certification standards, was required to complete the table. And for model years 2001 onwards, the factors were based entirely on this appreciation of the developments in initial certification standards.

The interpolation did not significantly affect the calculated emission reduction benefits from repairs to failing vehicles each year, because so few of the newer vehicles failed the test; and when they did, the absolute levels of reductions achievable by each repair were lower than from each repair to older vehicles. The result was that repairs to newer vehicles contributed very little to the overall amount of emission reduction from repairs.

Effect of Factors on Newer Passing Vehicles

However, as has been explained earlier in this report (**section 3.2**) Canada adopted the OBD requirements of Tier 1 certification in 1998; the US NLEV program was implemented in the North East states in 1999 and nationally in 2001; and although Tier 2 certification was not required until 2004, the technology necessary for compliance was implemented progressively in the preceding years. The OBD requirements and the US NLEV program did not require any change to the initial certification emissions performance of vehicles in Canada, compared to the existing Tier 1 requirements (implemented in 1996). So, in populating the mass-emission factor table, there was little reason to assume that the in-use emissions performance of the newer vehicles would be substantively different to the older Tier 1 vehicles (except for normal deterioration from age and use). So fairly conservative assumptions were made about how much cleaner the newest vehicles were becoming. These assumptions were brought into question by the results published in the previous program report, which reported emission reductions up to 2003.

An examination of that report will show that the rate of emission inventory reduction, modeled using the methodology and factors explained above, was less than the ongoing baseline (no Drive Clean Program) estimated using the MOBILE 6.2C model. This was because the emission factors assumed for the newer vehicles appeared to be too high. The result was that application of the emission factors to passing vehicles appeared to over-contribute to the overall emissions for almost all of the newer (passing) vehicles. Without reliable test data it was not possible to know how they should be adjusted. The only available source of such data for Canadian certified vehicles was the IM240 test program undertaken in British Columbia starting in 2001.

Updating Emissions Factors for Newer Vehicles

That dataset was large, comprising about 30,000 vehicles from all model years up to 2003, but it did not include ASM and idle results for newer vehicles. The ASM and idle results were needed for the Drive Clean mass-emission factor table, in order to be able to allocate factors appropriately, dependent on how the vehicle passed or failed its Drive Clean test.

In 2005 a project was undertaken to identify how each vehicle in the dataset would have fared in ASM and idle tests. The basis for identification was the second-by-second concentration data collected throughout every IM240 test. An initial feasibility approach only considered those test seconds that were reasonably equivalent to the ASM and idle test conditions. The final approach used a more sophisticated multiple regression model and considered all the available data. The result was a new set of mass emission factors, now based on IM240 mass test results. The new table entirely replaced the old table, which had been based on Hot505 test results from a much smaller sample of vehicles.

When applied to modelling the inventory at the start of each year, the new emission factors changed the emissions assigned to the older vehicles only a little, but greatly reduced emissions assigned to the newer vehicles. The effect on the 2004 inventory for Phase 1, shown in **Figure 7,** is most dramatic for model years 1992 and newer. The effect was similar in Phase 2 and Phase 3. The trend shown is now much more in line with results from MOBILE 6.2C, which show the

contribution of the newest vehicles continuing to decrease, even while their numbers and kilometres-driven increase.

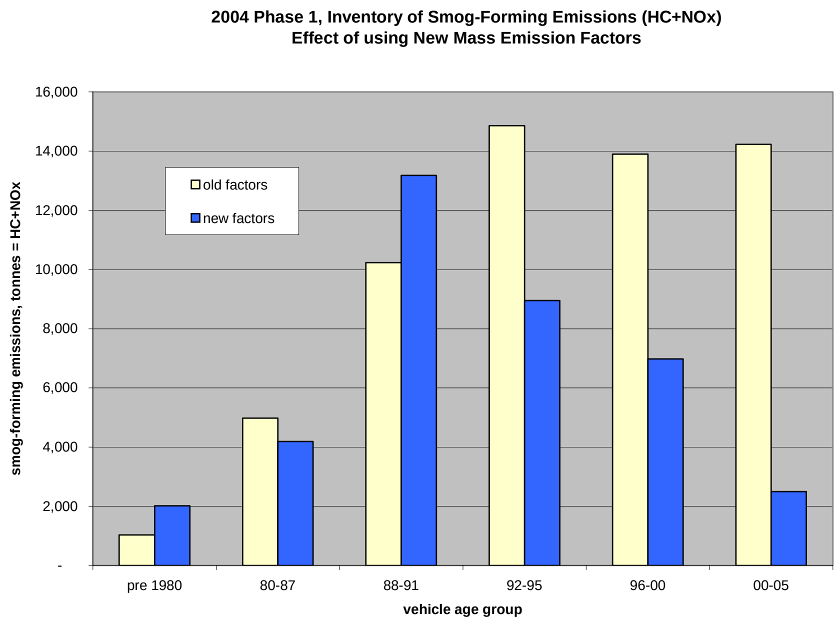



**Figure 7   Effect of Changing Emission Factors on 2004 Phase 1 Inventory**

### 3.4.4 Emission Reductions from New Repairs

The overall results from performing the above calculations, using the new emission factors, for each Phase in 2004 and 2005 are shown in **Appendix Tables A-4a to A-4f**. These tables also show the emissions from each age group and vehicle type, and the amount of emission reduction that new repairs (repairs done in the current year) have contributed.

The emission reductions were highest from the model years 1988-1991. Although more 1992-1995 vehicles failed the test than the 1988-1991 vehicles, the emission reductions achieved by their repair were lower. For the oldest model year group, 1980-1987, the failure rates were high, but few of them were subject to the program, so repairing them delivered limited emissions reductions. Ending the rolling exemption for LDVs, so that 1988 and newer LDVs stay in the program permanently starting in 2007, should gradually capture emissions reductions available from these vehicles in future years. The reductions in the 1996-2000 group and the 2001 and newer group were very small because very few failed the test and needed repair.

For all model year groups, repairs done to correct idle-only failures delivered much less emission reductions overall than those done in response to ASM failure.

For the entire fleet, **Table 6** shows the overall percentage reductions from new repairs in 2004.

**Table 6  Overall Percentage Emission Reductions from 2004 Repairs**

| | HC | CO | NOx |
|---|---|---|---|
| **Phase 1** | 7.9% | 8.1% | 4.8% |
| **Phase 2** | 7.5% | 7.6% | 4.2% |
| **Phase 3** | 4.0% | 4.9% | 2.8% |

These are all a little lower than was achieved in 2003, because fewer vehicles failed the test and therefore fewer vehicles were repaired.

For the entire fleet, **Table 7** shows the overall percentage reductions from new repairs in 2005.

**Table 7 Overall Percentage Emission Reductions from 2005 Repairs**

| | HC | CO | NOx |
|---|---|---|---|
| **Phase 1** | 7.2% | 7.9% | 5.6% |
| **Phase 2** | 6.2% | 6.6% | 4.5% |
| **Phase 3** | 5.3% | 6.6% | 4.4% |

HC and CO reductions in 2005 in Phases 1 and 2, were a little lower than was achieved in 2004, but NOx reductions increased slightly. In Phase 3 all the reductions were a little higher than in 2004, and are therefore closer to the values for Phase 1 and 2.

### 3.4.5 Baseline Emissions

The results were also compared with the default inventories that would have occurred if Drive Clean had not been implemented ("baseline emissions") as derived from MOBILE 6.2C. The MOBILE 6.2C model is the Canadian version of the MOBILE 6.2 model developed by the United States Environmental Protection Agency (US EPA).

The MOBILE 6.2C model was used to approximate the total emissions from vehicles in the calendar year at the start of each Phase. The model was also used to approximate the emissions for each subsequent calendar year that would have been expected if Drive Clean was not operating. The model predicts ongoing reductions with the retirement of older vehicles, introduction of vehicles with "cleaner" emissions control technologies, and improvements in fuels. At the same time the model accounts for the increasing emissions expected with fleet growth, increasing kilometers traveled, and changes in fleet characteristics such as a trend to large trucks and sport utility vehicles in the LDV fleet. The results from running the MOBILE model form the baseline inventory, to which the "actual" inventory with Drive Clean (i.e. an estimate of emissions from all vehicles each year, based on tailpipe emissions tests, with all factors considered), can be compared. All MOBILE 6.2C inventory modelling was performed by CW Environmental Consulting Inc. under separate contract to the Ontario Ministry of the Environment.

### 3.4.6 Preliminary Estimates of Inventory Reductions from Start of Drive Clean

**Tables 8, 9, 10** and **11** show how the inventory has changed from the start of the program in each Phase, through to 2005. On the left, they show the default no-Drive Clean inventory as modeled by MOBILE 6.2C; and on the right they show the preliminary inventory as derived from the calculations described above. The MOBILE 6.2C defaults assume that the registered and licensed fleet of vehicles would have been the same if the test program had not been implemented. The estimated inventory "with Drive Clean" columns assume that the inventory decreased in the proportions indicated by the calculations described in **section 3.4.1**.

The inventory with the Drive Clean program has continued to decrease in all Phases and for all measured pollutants. As shown in the table, since Phase 1 began in 1999 the smog-forming pollutants (HC+NOx) are estimated to have decreased by 68%. Over the same period Phase 2 smog-forming emissions are estimated to have decreased by 62%; and Phase 3 by 64%, compared to their 1999 values. These preliminary values are the total inventory reductions, from all causes including fleet turnover, cleaner vehicles and fuels, repairs required by the test program, and any other effects such as improved maintenance. (Phase 2 actually only started in 2001, and

Phase 3 in 2002, so the reductions in those Phases prior to those dates were entirely due to non-Drive Clean factors.) Without the Drive Clean program, the default reductions modelled by MOBILE 6.2C for the same periods would have been 35%, 39% and 40% for Phase 1, 2 and 3 respectively.

### Table 8 Phase 1: Change of Emissions Inventory 1999 to 2005

| | default inventory without DC (Tonnes or %) | | | | | preliminary estimated inventory with DC (Tonnes or %) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | HC | CO | NO | HC+NO | (HC+NO) % change | HC | CO | NO | HC+NO | (HC+NO) % change |
| 1999 | 48,851 | 796,747 | 46,672 | 95,523 | 0.0% | 44,587 | 726,371 | 44,656 | 89,243 | 6.6% |
| 2000 | 47,625 | 775,312 | 44,748 | 92,373 | 3.3% | 36,055 | 598,786 | 38,122 | 74,177 | 22.3% |
| 2001 | 45,177 | 738,257 | 42,942 | 88,119 | 7.8% | 32,168 | 544,057 | 34,333 | 66,501 | 30.4% |
| 2002 | 41,934 | 731,405 | 41,327 | 83,261 | 12.8% | 25,065 | 423,696 | 26,666 | 51,732 | 45.8% |
| 2003 | 37,872 | 686,554 | 38,061 | 75,933 | 20.5% | 22,575 | 379,894 | 23,833 | 46,407 | 51.4% |
| 2004 | 34,128 | 586,424 | 33,451 | 67,579 | 29.3% | 17,534 | 308,800 | 19,171 | 36,705 | 61.6% |
| 2005 | 30,977 | 535,240 | 30,870 | 61,847 | 35.3% | 14,532 | 259,855 | 15,907 | 30,439 | 68.1% |

### Table 9 Phase 2: Change of Emissions Inventory 1999 to 2005

| | default inventory without DC (Tonnes or %) | | | | | preliminary estimated inventory with DC (Tonnes or %) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | HC | CO | NO | HC+NO | (HC+NO) % change | HC | CO | NO | HC+NO | (HC+NO) % change |
| 1999 | 37,077 | 588,788 | 33,071 | 70,148 | 0.0% | 37,077 | 588,788 | 33,071 | 70,148 | 0.0% |
| 2000 | 36,317 | 574,773 | 31,882 | 68,199 | 2.8% | 36,317 | 574,773 | 31,882 | 68,199 | 2.8% |
| 2001 | 32,272 | 518,087 | 29,028 | 61,300 | 12.6% | 29,666 | 471,514 | 27,742 | 57,408 | 18.2% |
| 2002 | 29,560 | 502,837 | 27,490 | 57,050 | 18.7% | 23,248 | 369,316 | 21,613 | 44,861 | 36.0% |
| 2003 | 27,018 | 472,454 | 25,229 | 52,247 | 25.5% | 19,790 | 315,961 | 18,717 | 38,508 | 45.1% |
| 2004 | 24,332 | 410,804 | 22,416 | 46,748 | 33.4% | 15,262 | 254,494 | 14,983 | 30,245 | 56.9% |
| 2005 | 21,818 | 374,278 | 20,693 | 42,511 | 39.4% | 13,562 | 228,714 | 13,268 | 26,831 | 61.8% |

### Table 10 Phase 3: Change of Emissions Inventory 1999 to 2005

| | default inventory without DC (Tonnes or %) | | | | | preliminary estimated inventory with DC (Tonnes or %) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | HC | CO | NO | HC+NO | (HC+NO) % change | HC | CO | NO | HC+NO | (HC+NO) % change |
| 1999 | 22,910 | 364,375 | 20,173 | 43,083 | 0.0% | 22,910 | 364,375 | 20,173 | 43,083 | 0.0% |
| 2000 | 22,344 | 362,125 | 19,656 | 42,000 | 2.5% | 22,344 | 362,125 | 19,656 | 42,000 | 2.5% |
| 2001 | 21,382 | 342,584 | 18,813 | 40,195 | 6.7% | 21,382 | 342,584 | 18,813 | 40,195 | 6.7% |
| 2002 | 19,029 | 326,333 | 17,445 | 36,474 | 15.3% | 18,489 | 315,468 | 17,135 | 35,625 | 17.3% |
| 2003 | 16,907 | 298,117 | 15,608 | 32,515 | 24.5% | 15,161 | 259,929 | 14,511 | 29,672 | 31.1% |
| 2004 | 15,065 | 256,989 | 13,701 | 28,766 | 33.2% | 11,475 | 204,731 | 11,339 | 22,814 | 47.0% |
| 2005 | 13,428 | 231,012 | 12,552 | 25,980 | 39.7% | 7,881 | 137,386 | 7,550 | 15,432 | 64.2% |

**Table 11 All Phases: Change of Emissions Inventory 1999 to 2005**

| | default inventory without DC (Tonnes or %) | | | | | preliminary estimated inventory with DC (Tonnes or %) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | HC | CO | NO | HC+NO | (HC+NO) % change | HC | CO | NO | HC+NO | (HC+NO) % change |
| 1999 | 108,838 | 1,749,910 | 99,916 | 208,754 | 0.0% | 104,574 | 1,679,534 | 97,900 | 202,474 | 0.0% |
| 2000 | 106,286 | 1,712,210 | 96,286 | 202,572 | 3.0% | 94,716 | 1,535,684 | 89,660 | 184,376 | 8.9% |
| 2001 | 98,831 | 1,598,928 | 90,783 | 189,614 | 9.2% | 83,216 | 1,358,155 | 80,889 | 164,104 | 19.0% |
| 2002 | 90,523 | 1,560,575 | 86,262 | 176,785 | 15.3% | 66,802 | 1,108,479 | 65,415 | 132,217 | 34.7% |
| 2003 | 81,797 | 1,457,125 | 78,898 | 160,695 | 23.0% | 57,526 | 955,784 | 57,061 | 114,587 | 43.4% |
| 2004 | 73,525 | 1,254,217 | 69,568 | 143,093 | 31.5% | 44,271 | 768,026 | 45,493 | 89,764 | 55.7% |
| 2005 | 66,223 | 1,140,530 | 64,115 | 130,338 | 37.6% | 35,976 | 625,955 | 36,726 | 72,702 | 64.1% |

### 3.4.7 Adjusted Estimates of Inventory Reductions Due to Drive Clean

Before simply subtracting one set of estimates from the other (left and right sides of **Tables 8, 9, 10** and **11**) to deduce the effect of the Drive Clean program, it is important to consider the amount of uncertainty inherent in the estimates.

The MOBILE and direct emissions reduction estimates use different approaches and provide different results. The MOBILE model is a general evaluation of emissions from all LDVs under all expected driving conditions, whereas the independent estimate evaluated specific Drive Clean tailpipe results. Both estimation approaches make many assumptions and apply factors based on previous information. So it is reasonable to take a cautionary approach and apply an uncertainty factor to the emissions results especially when the results from two approaches are compared. We suggest that ± 20% is a reasonable uncertainty factor that could be applied to both MOBILE and direct estimates to avoid overestimating program benefits.

Consequently, the difference between these inventories, attributed to Drive Clean, can be reduced by 40% (20% plus 20%) to represent a conservative scenario. This factor has been applied to all of the following tables and charts, (but not to the charts shown in **Appendix A**, which show the preliminary results prior to application of the uncertainty factor).

The following table, Table 12, shows how the estimates in Table 8 have been adjusted using the 40% uncertainty factor. Likewise, the following graph, **Figure 8**, combines HC and NOx for Phase 1 from 1999 to 2005 and illustrates the overall trend, after having applied the -40% uncertainty factor. The dashed line, labeled 'no Drive Clean Baseline' is the MOBILE 6.2C default, modeled assuming the same fleet profile (i.e., assuming that the fleet turnover and old vehicle retirement rates without Drive Clean would have been the same as actually did occur with Drive Clean in place). It shows how the default emissions inventory would have come down simply as a result of fleet turnover (assuming the same turnover as did actually occur), and including the effects of cleaner vehicle technologies and fuels. Although the total number of in-use LDVs has continued to increase every year, the replacement of high-emitting older vehicles with new vehicles that meet ever more stringent new vehicle emissions standards, and continue to meet those standards longer, is enough to have reduced the emissions inventory substantially. The solid line, labeled 'with Drive Clean' indicates the results of the calculations derived from using the test data, and after having applied the 40% uncertainty factor. The effect of the 40% factor is to actually raise the position of the solid line to be 40% closer to the upper default line. Hence the vertical difference between the two lines has been reduced by 40% from what it would have been from simply applying the data in Table 8.

## Table 12   Phase 1: Adjusted Change of Emissions Inventory  1999 to 2005

| | default inventory without DC (Tonnes or %) | | | | | adjusted estimated inventory with DC (Tonnes or %) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | HC | CO | NO | HC+NO | (HC+NO) % change | HC | CO | NO | HC+NO | (HC+NO) % change |
| 1999 | 48,851 | 796,747 | 46,672 | 95,523 | 0.0% | 46,293 | 754,521 | 45,462 | 91,755 | 3.9% |
| 2000 | 47,625 | 775,312 | 44,748 | 92,373 | 3.3% | 40,683 | 669,397 | 40,773 | 81,456 | 14.7% |
| 2001 | 45,177 | 738,257 | 42,942 | 88,119 | 7.8% | 37,371 | 621,737 | 37,777 | 75,148 | 21.3% |
| 2002 | 41,934 | 731,405 | 41,327 | 83,261 | 12.8% | 31,813 | 546,779 | 32,531 | 64,343 | 32.6% |
| 2003 | 37,872 | 686,554 | 38,061 | 75,933 | 20.5% | 28,694 | 502,558 | 29,524 | 58,218 | 39.1% |
| 2004 | 34,128 | 586,424 | 33,451 | 67,579 | 29.3% | 24,171 | 419,850 | 24,883 | 49,055 | 48.6% |
| 2005 | 30,977 | 535,240 | 30,870 | 61,847 | 35.3% | 21,110 | 370,009 | 21,892 | 43,002 | 55.0% |

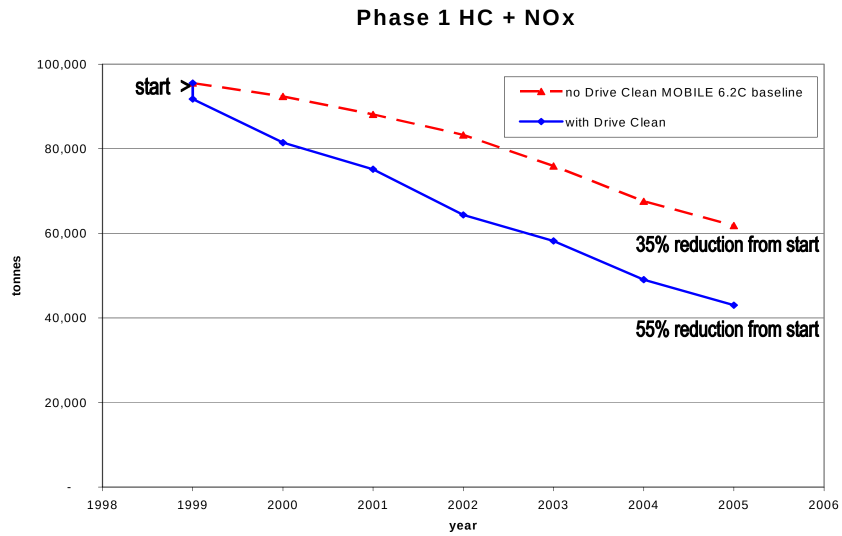



**Figure 8**

The starting point for each Phase was taken as equal to the inventory MOBILE 6.2C in the year the Phase was implemented, and the calculated inventory for each subsequent year relates back to that starting point. Thus, in the first year, the direct inventory values were made equal to the MOBILE emissions values and then the effect of the first year's repairs was to move the left end of the solid line a little lower than the dashed line. For subsequent years, the solid line shows the inventory that was achieved from the accumulation of all effects, including "old" and "new" repairs.

With the Drive Clean program, the observed inventories have come down at a faster rate than the ongoing MOBILE 6.2C baseline, indicating that Drive Clean is having a very profound effect on pollutants emitted to the air. The three contributing factors which can readily be identified are:

- Repairs performed in response to test failure
- Repairs performed in anticipation of testing
- Improved maintenance to avoid test problems

Only the first effect can be quantified from the available data, as no information has been collected on behavioural changes that resulted in vehicle owners improving regular vehicle maintenance, or performing repairs in anticipation of testing. We can only say that observed results include these effects.

Even though the incremental effect of new repairs each year has tended to decrease, as the failure rate has decreased, the solid "with Drive Clean" line continued to diverge from the dashed "no Drive Clean Baseline" line in the first few years of the program, but recently is closer to parallel.

We should note that the existence of the program will also have encouraged the earlier retirement of older vehicles, and their replacement with newer low-emitting vehicles. But, because this program effect can not be quantified, the default MOBILE inventory has assumed the same fleet make up as did actually occur (i.e., uses data with the program in place).

### 3.4.8 Total Emissions Reduced Since Program Implementation

Each year since implementation in each phase, the emissions inventory has been lower than it would have been if the program had not been implemented. The difference in emissions between the observed "with Drive Clean" case and the "no Drive Clean" case has generally increased each year for the first three or four years, and has then become more stable. The differences each year, after applying the -40% uncertainty factor, are shown on the left sides of **Tables, 13, 14** and **15** These values are 40% less than the difference between the left and right sides of **Tables 8, 9,** and **10**. The 40% has already been applied to the right side of **Table 12** so that the differences between the left and right side in that table match the differences shown in Table 13 for Phase 1. The total for all phases is shown in **Table 16.**

The left side base of each table shows the total tonnage of emissions reductions due to Drive Clean since its implementation in each Phase. When the Phases are added together, the total emissions reductions due to Drive Clean come to 83,365 tonnes of HC; 1,465,127 tonnes of CO, 67,610 tonnes of NOx, and 150,976 tonnes of HC+NOx.

The right sides of the tables show the Drive Clean reduction as a percentage of the baseline no-Drive Clean inventory in the year. **Table 16** shows that in 2005 the estimated effect of the program was to reduce the inventory of HC by 27.4% from what it would have been without the program; to reduce the CO inventory by 27.1%; to reduce NOx by 25.6%, and the combined HC+NOx inventory by 26.5%

**Table 13 Difference in Emissions Inventory, 1999 – 2005 Phase 1**

| | Inventory Difference in Year (tonnes) | | | | Inventory Difference as % of Baseline | | | |
|---|---|---|---|---|---|---|---|---|
| | HC | CO | NO | HC+NO | HC | CO | NO | HC+NO |
| 1999 | 2,558 | 42,226 | 1,210 | 3,768 | 5.2% | 5.3% | 2.6% | 3.9% |
| 2000 | 6,942 | 105,915 | 3,975 | 10,917 | 14.6% | 13.7% | 8.9% | 11.8% |
| 2001 | 7,806 | 116,520 | 5,165 | 12,971 | 17.3% | 15.8% | 12.0% | 14.7% |
| 2002 | 10,121 | 184,626 | 8,796 | 18,918 | 24.1% | 25.2% | 21.3% | 22.7% |
| 2003 | 9,178 | 183,996 | 8,537 | 17,715 | 24.2% | 26.8% | 22.4% | 23.3% |
| 2004 | 9,957 | 166,574 | 8,568 | 18,524 | 29.2% | 28.4% | 25.6% | 27.4% |
| 2005 | 9,867 | 165,231 | 8,978 | 18,845 | 31.9% | 30.9% | 29.1% | 30.5% |
| **Subtotals** | **56,429** | **965,088** | **45,229** | **101,658** | | | | |

**Table 14 Difference in Emissions Inventory, 2001 – 2005 Phase 2**

| | Inventory Difference in Year (tonnes) | | | | Inventory Difference as % of Baseline | | | |
|---|---|---|---|---|---|---|---|---|
| | HC | CO | NO | HC+NO | HC | CO | NO | HC+NO |
| 2001 | 1,564 | 27,944 | 771 | 2,335 | 4.8% | 5.4% | 2.7% | 3.8% |
| 2002 | 3,787 | 80,113 | 3,526 | 7,314 | 12.8% | 15.9% | 12.8% | 12.8% |
| 2003 | 4,337 | 93,896 | 3,907 | 8,244 | 16.1% | 19.9% | 15.5% | 15.8% |
| 2004 | 5,442 | 93,786 | 4,460 | 9,902 | 22.4% | 22.8% | 19.9% | 21.2% |
| 2005 | 4,953 | 87,339 | 4,455 | 9,408 | 22.7% | 23.3% | 21.5% | 22.1% |
| **Subtotals** | **20,083** | **383,077** | **17,119** | **37,202** | | | | |

**Table 15 Difference in Emissions Inventory, 2002 – 2005 Phase 3**

| | Inventory Difference in Year (tonnes) | | | | Inventory Difference as % of Baseline | | | |
|---|---|---|---|---|---|---|---|---|
| | HC | CO | NO | HC+NO | HC | CO | NO | HC+NO |
| 2002 | 324 | 6,519 | 186 | 510 | 1.7% | 2.0% | 1.1% | 1.4% |
| 2003 | 1,047 | 22,913 | 658 | 1,706 | 6.2% | 7.7% | 4.2% | 5.2% |
| 2004 | 2,154 | 31,355 | 1,417 | 3,571 | 14.3% | 12.2% | 10.3% | 12.4% |
| 2005 | 3,328 | 56,176 | 3,001 | 6,329 | 24.8% | 24.3% | 23.9% | 24.4% |
| **Subtotals** | **6,853** | **116,962** | **5,262** | **12,115** | | | | |

**Table 16 Difference in Emissions Inventory, 1999 – 2005 All Phases**

| | Inventory Difference in Year (tonnes) | | | | Inventory Difference as % of Baseline | | | |
|---|---|---|---|---|---|---|---|---|
| | HC | CO | NO | HC+NO | HC | CO | NO | HC+NO |
| 1999 | 2,558 | 42,226 | 1,210 | 3,768 | 2.4% | 2.4% | 1.2% | 1.8% |
| 2000 | 6,942 | 105,915 | 3,975 | 10,917 | 6.5% | 6.2% | 4.1% | 5.4% |
| 2001 | 9,369 | 144,464 | 5,936 | 15,306 | 9.5% | 9.0% | 6.5% | 8.1% |
| 2002 | 14,232 | 271,257 | 12,508 | 26,741 | 15.7% | 17.4% | 14.5% | 15.1% |
| 2003 | 14,563 | 300,805 | 13,102 | 27,665 | 17.8% | 20.6% | 16.6% | 17.2% |
| 2004 | 17,552 | 291,715 | 14,445 | 31,997 | 23.9% | 23.3% | 20.8% | 22.4% |
| 2005 | 18,148 | 308,745 | 16,433 | 34,582 | 27.4% | 27.1% | 25.6% | 26.5% |
| **Totals** | **83,365** | **1,465,127** | **67,610** | **150,976** | | | | |

### 3.4.9 Comparison with Previous Report

Because the mass emission factors have been updated, the previously published analyses were replaced by new analyses which use the new emission factors. The previously published estimates may have underestimated the total emission reductions over time because they underestimated how much cleaner newer vehicles are, compared to older ones, particularly in the most recent years of the program.

In fact, direct comparison of tonnages is complicated by the default MOBILE 6.2C estimates also having been revised slightly since the previous report.

If we examine the trends shown in **Figure 8** above, it is apparent that the rate of inventory decrease for the first three or four years after implementation of each phase is faster than would have occurred without the program. From about the fourth year after implementation, the two lines become much more parallel, which indicates about equal rates of inventory reduction. (This second stage has not been reached yet for Phase three) The interpretation is that during its first years the program identifies, and requires repair of, a large number of vehicles that have developed unaddressed problems over the preceding years. Later, after all vehicles have undergone about two cycles of testing, the prevalent effect is to identify vehicles which have developed problems since their previous test cycle. In this latter phase, the program is essentially ensuring that most vehicles continue to operate as they should, instead of being allowed to deteriorate unchecked. Continued reductions to the baseline are caused by improvements in technology and certification standards; and the effect of repairs is to keep the 'with Drive Clean' line about the same distance below the 'no Drive Clean' line. It was this latter phase which was most clearly not adequately modeled by the emission factors used as the basis for the previous report.

As was explained in **section 3.4.3**, the previous set of mass emission factors was adequate for modelling the amount of emission reductions directly attributable to new repairs each year - performed in response to having failed the Drive Clean test. The new factors have not changed the result of that particular calculation very much. What has changed is the section of the inventory calculated for the large number of newer vehicles which did not fail the test. This part of the inventory was previously being overestimated in the "with Drive Clean" scenario. (but not in the "no Drive Clean" baseline which was independently modeled using MOBILE 6.2C). So the total difference between "with Drive Clean" and the "no Drive Clean" baseline was not as much as it should have been for the most recent years of the program. Updating the emission factors has corrected that problem. It has not changed the amount of reduction directly accredited to new repairs in the year, but it has more properly modeled the overall cumulative effects of the Drive Clean program over time.

### 3.4.10 Impact on Fuel Consumption and $CO_2$

Fuel consumption is often affected by the repairs intended to correct an emissions problem. Although it is common to expect such repairs to improve fuel consumption, in some cases a good repair can actually result in increased fuel consumption. Taking this into account, the average fuel consumption improvement for all repaired vehicles has been estimated as 2% [a]

During 2004, 223,530 vehicles failed their initial emissions test and were repaired partially, or completely. For 2005 the number was 229,028.

Using an average annual travel distance of 16,000 km, and assuming average fuel consumption at about 10 litres/100 km, and an average repair life of two years [b], these new repairs would save about 29 million litres over their two year life. [c]

Assuming that emissions of 2.5 kilograms of carbon dioxide are prevented for every litre of fuel saved, this would equate to a reduction in carbon dioxide emissions of more than 70,000 tonnes.[d]

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[a] "The Effect of Emission Repairs on Fuel Consumption and $CO_2$ Emissions" Stephen Stewart, Jimmy Wong 14th CRC On-Road Vehicle Emissions Workshop, San Diego. April 2004

[b] An unpublished SBA analysis of Drive Clean data from 1999 to 2004 showed that over half of the vehicles repaired, which were subsequently tested in the next biennial cycle, passed that subsequent test. This result agreed with another unpublished analysis by UBC of British Columbia AirCare data, which concluded an average repair life of over 2 years.

[c] **452,558** vehicles x **2** years x **16,000** km/y x **10** litre/100km x **2%** = **28,963,712** litres saved

[d] **28,963,712** litres x **2.5** kgCO2/litre = **72,409** tonnes $CO_2$

Carbon Dioxide emission reductions from the start of the program in 1999 to 2003 were previously estimated at 100,000 tonnes. So the total savings from 1999 to 2005 were about 170,000 tonnes.

## 3.5 Repairs

### 3.5.1 Repair Statistics

The test process identifies problem vehicles, but by itself does not reduce emissions. The repairs carried out in response to failing a Drive Clean test deliver a large part of the program benefits. However, there are also other sources of emissions reduction benefits such as repairs performed in anticipation of a required test, improved overall vehicle maintenance that is encouraged by an awareness of the environmental costs of poor maintenance, and the early retirement of some vehicles which are simply not worth repairing to pass the test. All of these are effects desired when implementing a test and maintenance program such as Drive Clean.

A separate appendix presents the repair data submitted for those vehicles that were repaired at Drive Clean Facilities after having failed the test. It identifies which repair actions were most commonly carried out, and also the most common overall diagnoses. It must be remembered that not all diagnosed problems are repaired, because motorists may choose to limit their costs by taking advantage of the Repair Cost Limit of $450.

### 3.5.2 Repair Effectiveness

The repair success rate can be used as an indicator of repair effectiveness. Detailed information on repair success rates for 2004 and 2005 is presented in the appendix. Most of the repairs were successful in terms of achieving a Pass. The success rate for 2005 is plotted by vehicle type and model year in **Figure 9**. It appears that repairs to later model vehicles were more likely to be successful than those to older vehicles. There was no difference in the likelihood of success for cars and trucks.

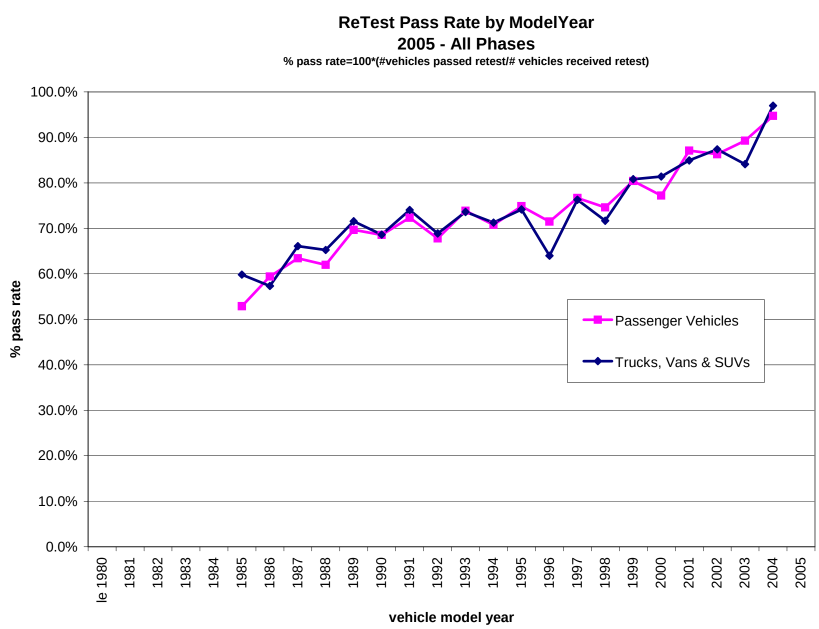


**Figure 9**

# 4 HEAVY-DUTY NON-DIESEL VEHICLES

## 4.1 Vehicle Numbers and Failure Rates

Vehicles which are heavy-duty are mostly diesels, and are tested using the SAE J1667 procedure. Those which are not powered by diesel engines are tested using a two-speed-idle test. The numbers of non-diesel heavy-duty vehicles tested are summarized in **Table 17**. Their total was 17,541 in 2004, much higher than in previous years, and dropped back to 8,872 in 2005. The total number is very small compared to the numbers of heavy-duty diesels and LDVs.

**Table 17 Heavy-Duty Non-Diesel Two-Speed Idle Statistics**

| | 2004 | | | | 2005 | | | |
|---|---|---|---|---|---|---|---|---|
| **GASOLINE** | **phase 1** | **phase 2** | **phase 3** | **total** | **phase 1** | **phase 2** | **phase 3** | **total** |
| ALL MODEL YEARS | | | | | | | | |
| **number inspected** | 5967 | 6434 | 3810 | 16211 | 2931 | 3580 | 1896 | 8407 |
| **number failed** | 904 | 1276 | 826 | 3006 | 393 | 591 | 373 | 1357 |
| **% failed** | 15% | 20% | 22% | 19% | 13% | 17% | 20% | 16% |
| PRE-1991 | | | | | | | | |
| **number inspected** | 1963 | 3314 | 2025 | 7302 | 934 | 1563 | 891 | 3388 |
| **number failed** | 568 | 980 | 675 | 2223 | 238 | 437 | 304 | 979 |
| **% failed** | 29% | 30% | 33% | 30% | 25% | 28% | 34% | 29% |
| POST-1990 | | | | | | | | |
| **number inspected** | 4004 | 3120 | 1785 | 8909 | 1997 | 2017 | 1005 | 5019 |
| **number failed** | 336 | 296 | 151 | 783 | 155 | 154 | 69 | 378 |
| **% failed** | 8% | 9% | 8% | 9% | 8% | 8% | 7% | 8% |
| **NATURAL GAS** | | | | | | | | |
| **number inspected** | 225 | 80 | 17 | 322 | 66 | 13 | 4 | 83 |
| **number failed** | 26 | 8 | 4 | 38 | 2 | 1 | 1 | 4 |
| **% failed** | 12% | 10% | 24% | 12% | 3% | 8% | 25% | 5% |
| **PROPANE** | | | | | | | | |
| **number inspected** | 439 | 437 | 132 | 1008 | 151 | 181 | 50 | 382 |
| **number failed** | 116 | 120 | 55 | 291 | 39 | 49 | 14 | 102 |
| **% failed** | 26% | 27% | 42% | 29% | 26% | 27% | 28% | 27% |
| **ALL FUELS** | | | | | | | | |
| **number inspected** | 6631 | 6951 | 3959 | 17541 | 3148 | 3774 | 1950 | 8872 |
| **number failed** | 1046 | 1404 | 885 | 3335 | 434 | 641 | 388 | 1463 |
| **% failed** | 16% | 20% | 22% | 19% | 14% | 17% | 20% | 16% |

The majority of these vehicles were gasoline, followed by propane and natural gas. Their overall failure rate was 19% in 2004 and 16% in 2005. The propane failure rate was close to 30%. The failure rates showed a continuing decline from previous years.

For gasoline vehicles, the numbers and rates have been separated into pre-1991 model years, and post-1990. This lines up with the groupings used for diesel powered heavy duty vehicles tested using SAE J1667 diesel cutpoints. 2004 was the first year in which more post-1990 vehicles were tested than pre-1991 vehicles. Although the failure rates for both age groups were lower in 2005 than in 2004, the failure rate for pre-1991 vehicles (29%) continued to be much higher than for the newer vehicles (8%).

## 4.2 Emission Estimates

Emission rates have been approximated from the GWT Consulting report of 2002, and annual kilometres driven have been calculated from odometer readings. The overall emissions from the heavy-duty gasoline vehicles are summarized in **Table 18**.

**Table 18 Emission Rates and Reductions – Heavy-Duty Non-Diesel Vehicles**

| | | tonnes/year HC | | tonnes/year CO | | tonnes/year NOx | |
|---|---|---|---|---|---|---|---|
| | | 2004 | 2005 | 2004 | 2005 | 2004 | 2005 |
| **PHASE 1** | <1991 | 323 | 140 | 2839 | 1235 | 474 | 207 |
| | >1990 | 430 | 214 | 3691 | 1837 | 701 | 350 |
| | **total** | **754** | **354** | **6530** | **3072** | **1174** | **557** |
| | **repair reduction** | 57 | 23 | 289 | 120 | 4 | 2 |
| **PHASE 2** | <1991 | 476 | 217 | 4161 | 1902 | 691 | 317 |
| | >1990 | 337 | 216 | 2885 | 1855 | 546 | 353 |
| | **total** | **813** | **433** | **7045** | **3757** | **1237** | **670** |
| | **repair reduction** | 78 | 35 | 393 | 179 | 6 | 3 |
| **PHASE 3** | <1991 | 276 | 120 | 2391 | 1039 | 392 | 171 |
| | >1990 | 192 | 107 | 1646 | 922 | 312 | 176 |
| | **total** | **468** | **227** | **4037** | **1962** | **705** | **346** |
| | **repair reduction** | 50 | 22 | 249 | 109 | 4 | 2 |

All Phases and emissions show major decreases from 2004 to 2005. This can be attributed to the decrease in the number of vehicles tested. Because of this variability in the numbers tested each year, it is impossible to use the test data to make any reliable statement about how the inventory contributions from this class of vehicles are changing. What we can derive from the test data is a picture of how many vehicles initially failed test, and were later retested to pass. These numbers were used to calculate the amount of emissions reductions due to repairs, and this is indicated in the table. Because the test is only a two-speed-idle, the emission reductions were generally for HC and CO. The small NOx reductions were merely incidental to some of these idle repairs. As percentages of the emissions that would have been experienced without Drive Clean, the emission reductions in 2005 were 8% for HC; 5% for CO, and ~0% for NOx. However, the tonnage reductions are small compared to those from LDVs, because there are so few non-diesel heavy duty vehicles.

# 5 CONCLUSIONS

## 5.1 Test Statistics

The total number of LDV tests performed in 2005 was higher than in 2004; this was true for all three Phases. However, the overall statistical patterns of age profiles, failure rates, and retest success rates, etc, changed in two ways:

- a continuation of the trend towards lower failure rates each year, as expected because vehicles have already been repaired in previous test cycles
- the maturing of Phase 3 such that failure rates are now essentially the same in all Phases.

## 5.2 Emission Reductions

The effect of new repairs was to lower the inventory, but for all Phases the tonnage reduction directly attributable to new repairs was less for 2005 than for 2004. This is a direct result of the decreased failure rates and also the decreased inventory itself. The percentage inventory reductions due to new repairs showed the same convergence of Phases as is evident from the failure rates. Phase 3 has improved emissions reductions for HC, CO and NOx, whereas Phases 1 and 2 showed less percentage reduction for HC and CO than in 2004, but more NOx reduction.

By 2005, the total vehicle emission inventory decrease with Drive Clean began to parallel the rate that would have occurred without the Drive Clean program but with Drive Clean emissions were much lower. This means that tens of thousands of tonnes of smog-causing pollutants were not emitted by vehicles each year because Drive Clean was in place.

By 2005:

- Phase 1 inventory of HC+NOx was 55% lower than at implementation in 1999, compared to a no-program estimate of only 35%;
- Phase 2 HC+NOx was 44% lower than at implementation in 2001, compared to a no-program estimate of 31%;
- Phase 3 HC+NOx was 45% lower than at implementation in 2002, compared to a no-program estimate of 29%.

In 2005:

- Phase 1 emissions reductions of HC+NOx with Drive Clean lowered the default inventory (emissions that would have been expected that year without Drive Clean) by 30.5%;
- Phase 2 emissions reductions of HC+NOx with Drive Clean lowered the default inventory by 22.1%;
- Phase 3 emissions reductions of HC+NOX with Drive Clean lowered the default inventory by 24.4%;
- In all three Phases, total emissions reductions of Drive Clean lowered the total default inventory by 26.5% (reduced emissions by 34,582 tonnes from the estimated 130,338 tonnes of smog-causing vehicle emissions that Ontario would be subjected to without Drive Clean).

## 5.3 Repairs

Repairs continue to be effective, resulting in most vehicles passing a re-test. The frequencies and patterns of diagnosed and repaired items are very simple (i.e., the most common diagnoses are the catalytic converter, or the oxygen sensor, or EGR system). However, although the number of catalytic converters which were diagnosed as faulty was high, the Repair Cost Limit appears to have limited the frequency with which catalytic converters were actually replaced. In principle, more program emission reduction benefit could be achieved by eliminating or raising the Repair Cost Limit, so that additional repairs would be performed, and more retested vehicles would Pass instead of Conditionally Passing.

## 5.4 Heavy-Duty Non-Diesel Vehicles

There are very few non-diesel heavy-duty vehicles. Their total contribution to the emissions inventory is very small. Moreover, the data on numbers tested each year tends to vary, and there is no really reliable source for appropriate emission factors. Although emission reductions have been calculated, expressed as tonnages they are orders of magnitude less significant than the calculations for LDVs. At the same time, inclusion in Drive Clean is important as these vehicles have, on average, higher failure rates to LDVs, and individual vehicles can be gross polluters just like LDVs.

## 6 APPENDIX A -- Tables and Figures



## 7 APPENDIX B – Repairs